Center for Independent Experts (CIE) External Independent Peer Review

Assessment of the Pacific cod stocks in the Eastern Bering Sea and Aleutian Islands

By

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For the
Center for Independent Experts

April 2016

Executive Summary

The review panel chair did excellent work at keeping the discussions flowing smoothly to ensure that work progressed at a good pace and sensibly. The assessment team was very useful, cooperative and their help is greatly appreciated. This was a pre-assessment review where the Center for Independent Experts (CIE) panelists did not have to agree or disagree with one or more assessments. Instead, the purpose was to get input into possible avenues to explore or others to avoid. The assessment team has done a very thorough job at preparing runs before the meeting and at replying to requests during the meeting.

From what was discussed during the meeting and the documentation reviewed, there are no objective reasons to reject the IPHC longline survey as an index of stock size, assuming it has been correctly put together and calculated. The IPHC longline survey data should be thoroughly investigated. It should be used in the assessment unless fatal flaws in the data, in the treatment of the data or in the survey methodology are identified. Similar to the IPHC longline survey, there are no objective reasons to reject the AFSC longline survey as an index of stock size. The AFSC longline survey should also be thoroughly investigated and used in the assessment unless fatal flaws in the data, in the data treatment or in the survey methodology are identified.

Regarding the form of the selectivity function, my preference would be to **not** allow too much flexibility in selectivity changes over time and to **not** allow strange patterns (e.g. figures 2.1.3 in the Eastern Bering Sea and 2A.11 and 2A.12 in the Aleutian Islands in the December 2015 SAFE report). If allowing these strange patterns is a condition of getting a good fit or convergence, this would be a sign that something else might be wrong. If allowed to change over time and age, the changes should be relatively smooth and not result in peculiar patterns. The reason(s) for the apparent differences in selectivity between the IPHC longline survey and the AFSC longline survey for lengths above 70cm should be further investigated.

It could be worth investigating further changes in growth (Figure 11), particularly with respect to the implications for the assessment as growth changes may have an influence on fishing mortality and population estimates.

In the Aleutian Islands area, it is unlikely that there is a single stock in the traditional understanding of the concept. Simpler form of monitoring and management, in close cooperation with the industry and possibly NGOs, could be a better way of protecting the resources and managing the fisheries.

One cannot model oneself out of lack of data, particularly for the Aleutian Islands assessment. Stock Synthesis has so much flexibility that, given sufficient time, a skilled user can probably get almost any stock trend from a dataset. Indices of abundance should be given more weight in the assessment than length composition. Age composition, particularly from the commercial fishery, but also from surveys or other indices of abundance can be very informative if analyzed

appropriately. Information in the length composition is at best indirect information on changes in stock size.

Analytical retrospective analyses are routinely done for both stocks. Historical retrospective, where there are successive accepted assessments, is also informative and should be done to indicate how consistent the assessments have been over time. Simpler models, e.g. like Robin Cook's or surplus production models should be investigated. It is not necessary to go to Ensemble modeling, but looking at more than one modeling framework might be informative.

Background

The Pacific cod stock assessment has a long history in the Eastern Bering Sea and the Aleutian Islands dating back to at least the early 1980s. Prior to 1985, the advice was based on simple projections of the current survey numbers at age. In 1985, the advice was based on projections of the 1979 to 1985 survey numbers at age. During 1986 to 1991, the assessment used an ad hoc separable age-structured model. Since 1992, the assessment uses Stock Synthesis in various forms and configurations (age based, length based, age and length based). While the assessment has varied over time and considerable investigations of almost all configurable parameters have been done since 2005, the "engine" of the assessment has remained successive versions of Stock Synthesis.

Originally, the Aleutian Island Pacific cod stock was not assessed separately from the Eastern Bering Sea stock, and a single OFL and ABC were established for both areas until 2011. Prior to the 2004 assessment, results from the Eastern Bering Sea model were inflated into Eastern Bering Seas Aleutian Island -wide equivalents using ratios based on survey biomass point estimates from the two regions. After 2004, the ratios were based on smoothed survey biomass estimates generated by a random-walk Kalman filter. Models for separate management of the Aleutian Islands stock were first proposed in 2011 were only adopted in 2013. The accepted model has been constant since 2013, a Tier 5 model based on either Kalman filter or a simple random effects model, similar to the Kalman filter approach. The Tier 5 approach implies more precaution in management and consequently lower OFL and ABC. An age-structured model should allow better utilization of the resource and higher allowable catches.

Despite exploration of a large number of alternative models and extensive peer review each year, the annual assessments of the Pacific cod stocks in the Eastern Bering Sea and Aleutian Islands continue to be controversial. While the estimation of catchability and selectivity for the bottom trawl survey in each area is currently of concern, this review is expected to deal with all aspects of the stock assessment models. The combined Pacific cod fisheries in the Eastern Bering Sea and Aleutian Islands are of great economic importance, ranking second only to pollock in recent years. For the Aleutian Islands, some persistent issues include: i) the age-structured SS models consistently tended to estimate strongly “pointed” survey selectivity, unless forced to do otherwise; ii) models tended to estimate catchability less than 1, unless forced to do otherwise; iii) together, the above results meant that the models tended to estimate total biomass 2-4 times higher than the survey biomass. The assessment leaders, the PDT, and the SSC were all reluctant to accept this result without independent confirmation that it was correct.

Description of the Individual Reviewer’s Role in the Review Activities

I read the Pre-review background documents (http://www.afsc.noaa.gov/REFM/Stocks/plan_team/2016pcodCIE/draft_assessments.htm) and participated in the review at the Alaska Fisheries Science Center (AFSC) in Seattle. I arrived

in Seattle a day later than planned. My in-bound plane was diverted to Providence, RI, where I slept on Monday night because JFK, my connecting airport, was closed due to freezing rain.

Summary of Findings for each ToR

1. Evaluate and provide recommendations on data used in the assessment models. In particular:

a. Should data from the IPHC longline survey be used in either assessment?

During the review meeting it was not clear if the raw data received from the International Pacific Halibut Commission (IPHC) had been treated appropriately to derive an index of stock size. Further work was conducted by the AFSC survey unit during the meeting, and it seems that the series shown in the excel spreadsheet "*Survey index comparison (trawl surveys, longline surveys).xlsx* " could be treated as an index of stock size. The appropriateness of the data and how it was treated to calculate an index should be further verified between now and the assessment meeting later in the year. What data were used and how they were used should also be documented.

The IPHC longline survey has been conducted every year since 1997. The survey covers the Eastern Bering Sea area well (Figure 1) but it is not clear[1] if all stations were used in calculating a relative index or if only those on the slope were used.

The main index of abundance used in the Eastern Bering Sea stock assessment is the AFSC shelf trawl survey. The agreement between the AFSC shelf trawl survey and the IPHC longline survey is not very good (Figure 2). This could be due to different size selectivities and / or inherent variability in the data.

The IPHC longline survey sample larger individuals (Figure 3) and a lag between the two indices would therefore be expected. However, the sudden decreases in the relative index in 1999 and 2005, and similarly sudden increase in the following year are unlikely to reflect real changes in stock sizes. These anomalies warrant further investigations to try to identify what might cause them. If there are valid reasons to exclude those two points, it might be possible to reconcile the IPHC longline and AFSC shelf trawl survey time series taking into account that they sample different size groups.

Including longline surveys (IPHC or AFSC) in the assessment might alleviate concerns that the shelf trawl survey samples poorly larger sizes, either because large Pacific cod are outside of the surveyed area or because they are able to swim faster than the fishing gear and therefore escape capture. Including one or more indices of stock sizes for larger fish sizes therefore has the potential to improve the assessment and reduce the uncertainty in the population estimates of larger fish sizes.

[1] The figure itself is not very clear either but that is the best I could find.

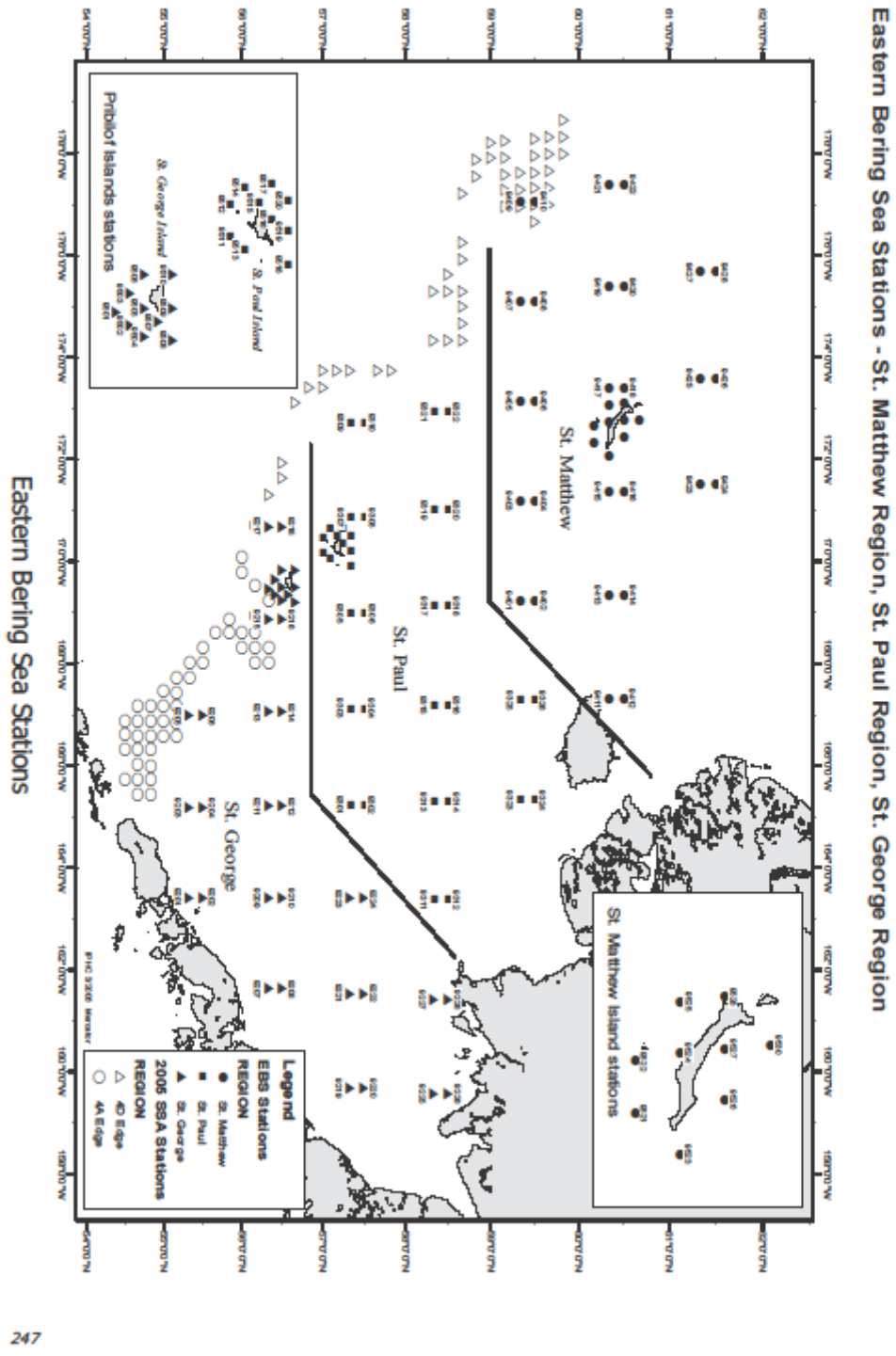

Figure 1: Stations of the IPHC longline survey in the Eastern Bering Sea (from http://www.iphc.int/data/survey/2006/ebsmap2006.pdf).

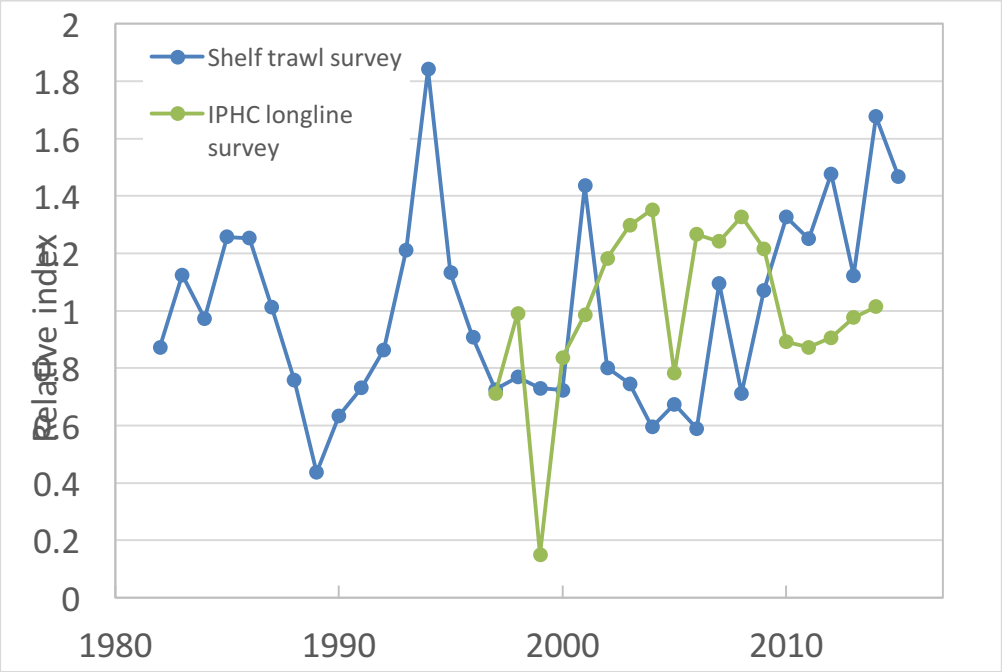

Figure 2: Relative indices for the AFSC shelf trawl survey and the IPHC longline survey (adapted from spreadsheet "*Survey index comparison (trawl surveys, longline surveys).xlsx*" prepared by the assessment team).

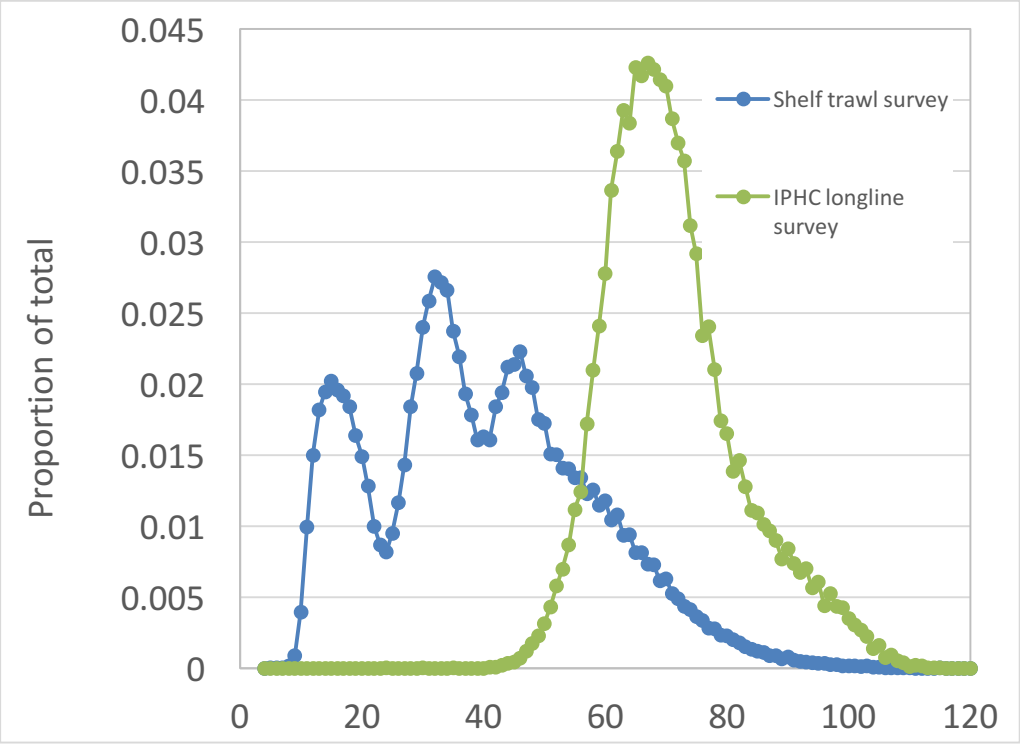

Figure 3: Size composition of the AFSC shelf survey and the IPHC longline survey (adapted from the file "*Long-term sizecomp comparison (trawl surveys, longline surveys, longline fishery).xlsx*).

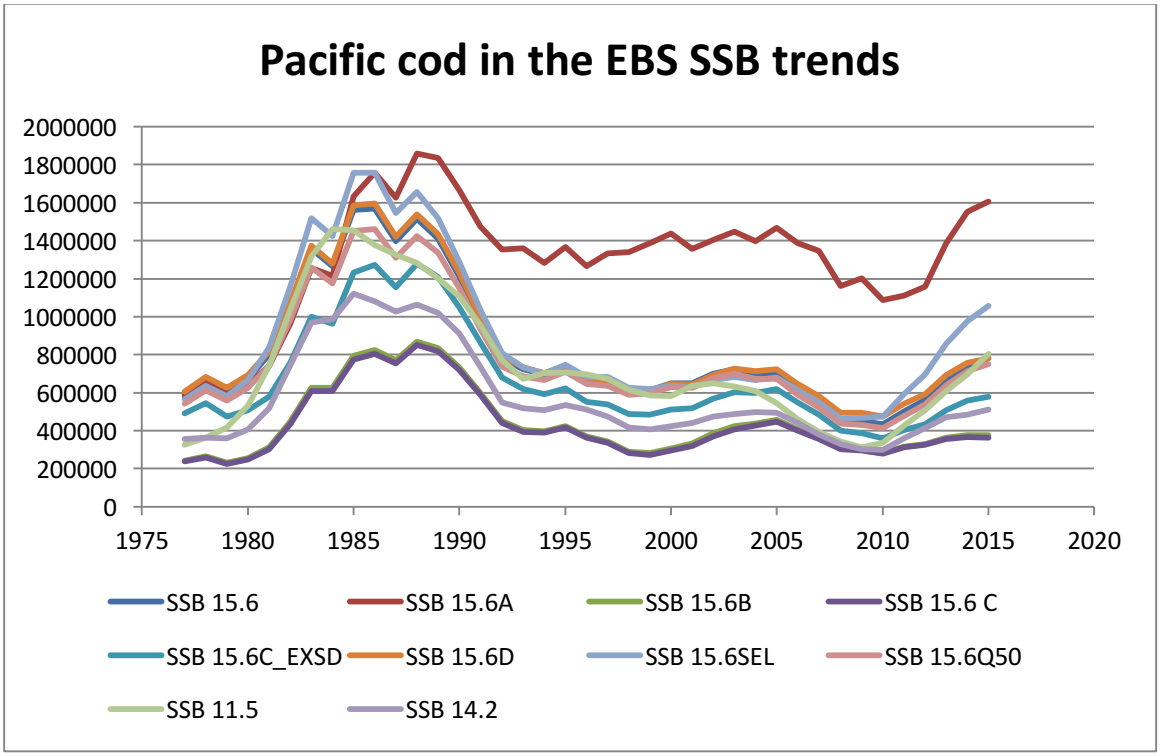

Figure 4: Eastern Bering Sea Pacific cod, SSB trends from various model configurations.

Figure 4 shows the spawning stock biomass (SSB) trends for the Eastern Bering Sea Pacific cod stock from various model configurations. I have not been able to find a model where only the IPHC longline survey is added to the AFSC shelf trawl survey, but I think one was presented during the meeting. My memory is that including data from the IPHC longline survey in the assessment implies lower terminal year biomass than when only the shelf trawl survey is used. Figure 4, however, shows that when both the IPHC longline survey and the AFSC longline survey are added (model 15.6B), the SSB estimates are the lowest of the model considered. Adding the AFSC slope trawl survey (model 15.6C) implies essentially identical results to adding the two longline surveys. Adding only the AFSC longline survey (model 15.6A) results in a SSB trend that is markedly different from those of the other models considered.

From what was discussed during the meeting and the documentation reviewed, there are no objective reasons to reject the IPHC longline survey as an index of stock size, assuming it has been correctly put together and calculated. Its influence on the assessment results, however, when used along with the AFSC longline survey is puzzling.

The IPHC longline survey data should be thoroughly investigated. I should be used in the assessment unless fatal flaws in the data, in the treatment of the data or in the survey methodology are identified.

b. Should data from the NMFS longline survey be used in either assessment?

The AFSC longline survey was developed as an index of abundance for sablefish, but recently, the results have also been found useful as indices of abundance for rougheye rockfish,

blackspotted rockfish, and for black halibut (aka Greenland turbot). Similar to the IPHC longline survey, the AFSC longline survey started in 1997, but it is conducted during odd years in the Eastern Bering Sea and during even years in the Aleutian Islands. In the Gulf of Alaska, the survey is conducted every year. There are few stations in the Eastern Bering Sea and in the Aleutian Islands, but they do cover the expected area of distribution of larger Pacific cod (Figure 5).

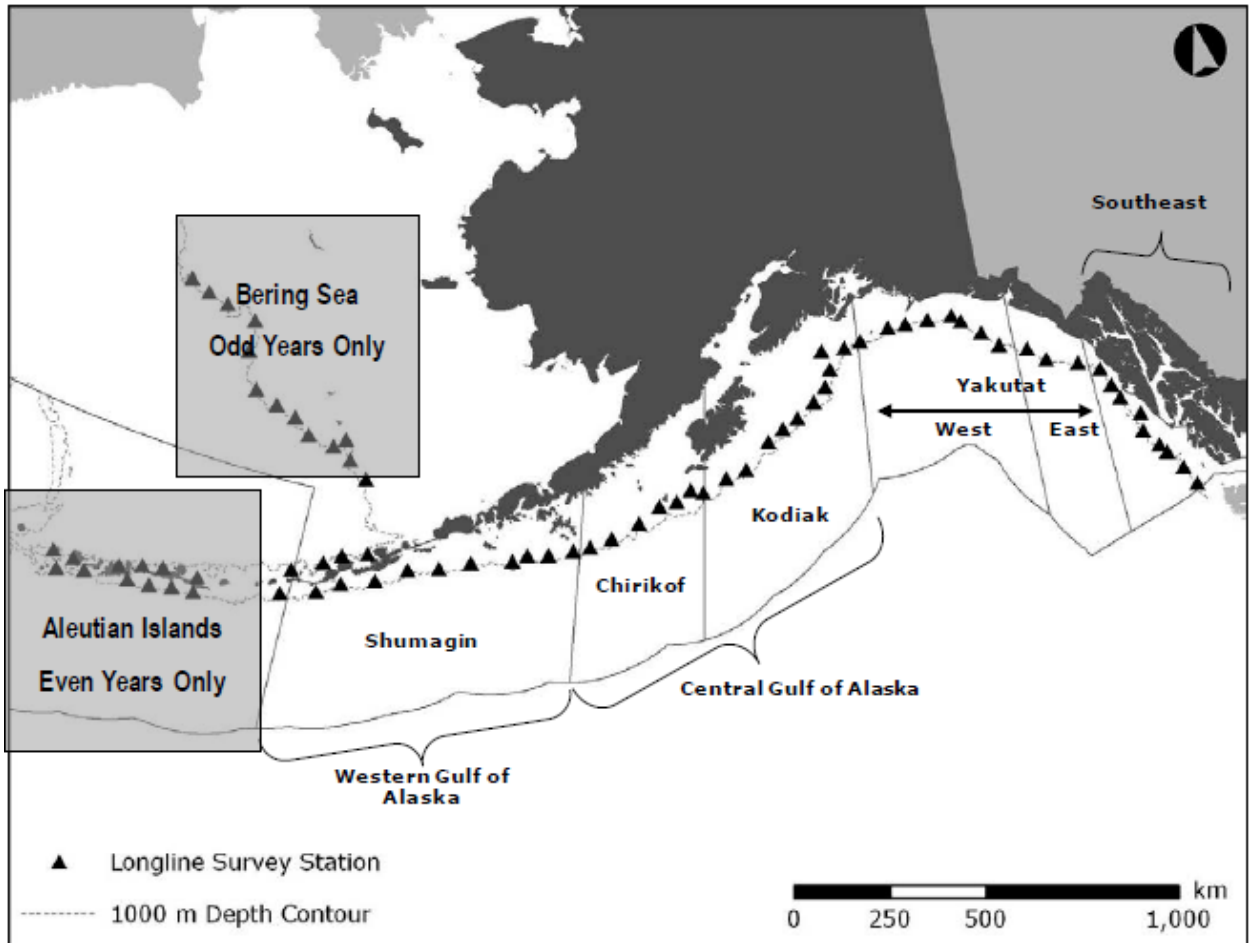

Figure 5: Coverage of the AFSC longline survey (from the presentation prepared by Dana Hanselman for the review).

The agreement between the AFSC shelf trawl survey and the AFSC longline survey (Figure 6) is better than between the AFSC shelf trawl survey and the IPHC longline survey. The AFSC longline survey, similar to the IPHC longline survey, catch different sizes than the AFSC shelf trawl survey (Figure 7).

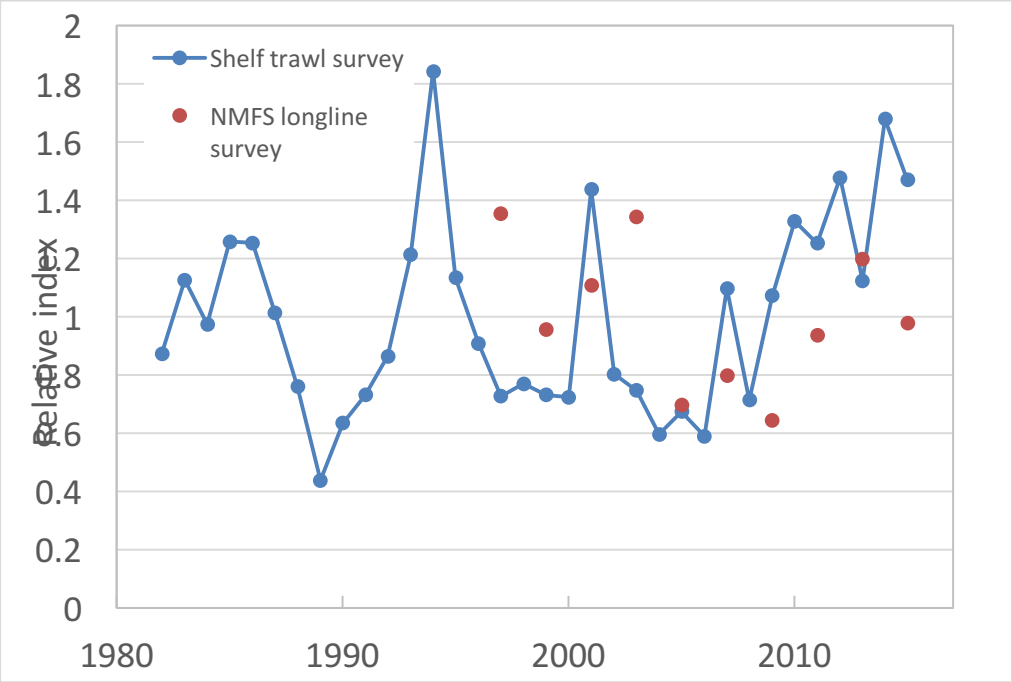

Figure 6: Relative indices for the AFSC shelf trawl survey and the AFSC longline survey (adapted from spreadsheet "*Survey index comparison (trawl surveys, longline surveys).xlsx*" prepared by the assessment team).

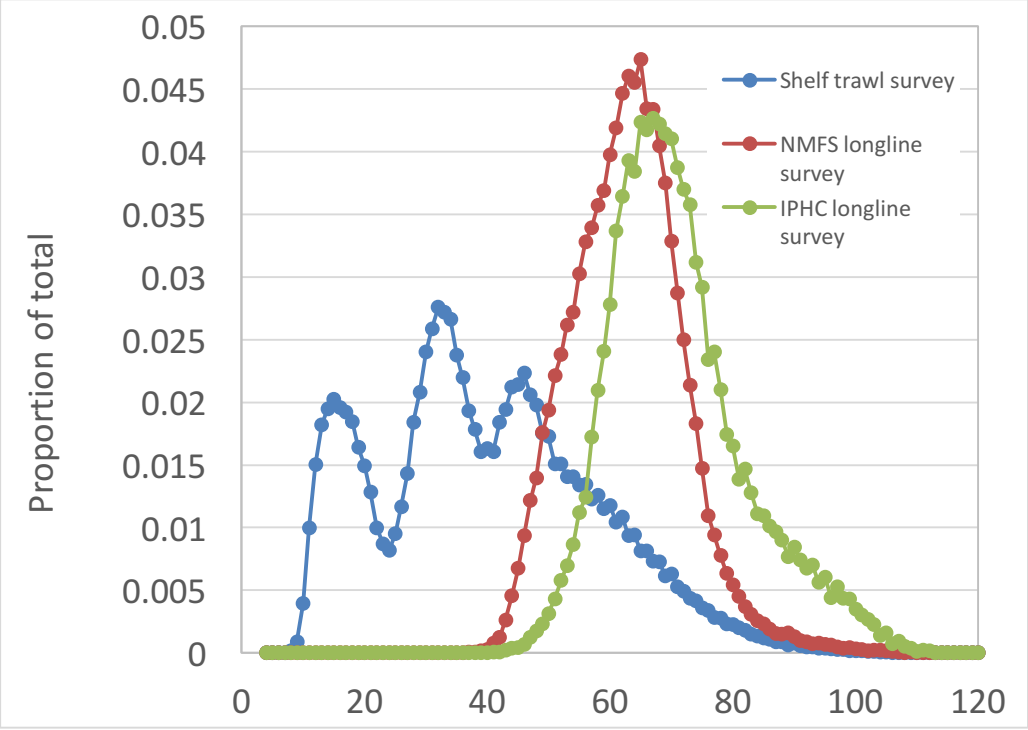

Figure 7: Size composition of the AFSC shelf survey, The AFSC longline survey and the IPHC longline survey (adapted from the file "*Long-term sizecomp comparison (trawl surveys, longline surveys, longline fishery).xlsx*")

The agreement between the AFSC longline survey and the IPHC longline survey (Figure 8) is poor overall. The two apparently anomalous points in the IPHC longline survey in 1999 and 2005 may explain in part the discrepancy, but differences in the area surveyed, in the timing of the survey and slight differences in the size composition may also play a role (keeping in mind that further work may be needed to confirm that the index derived from the IPHC longline survey is appropriate).

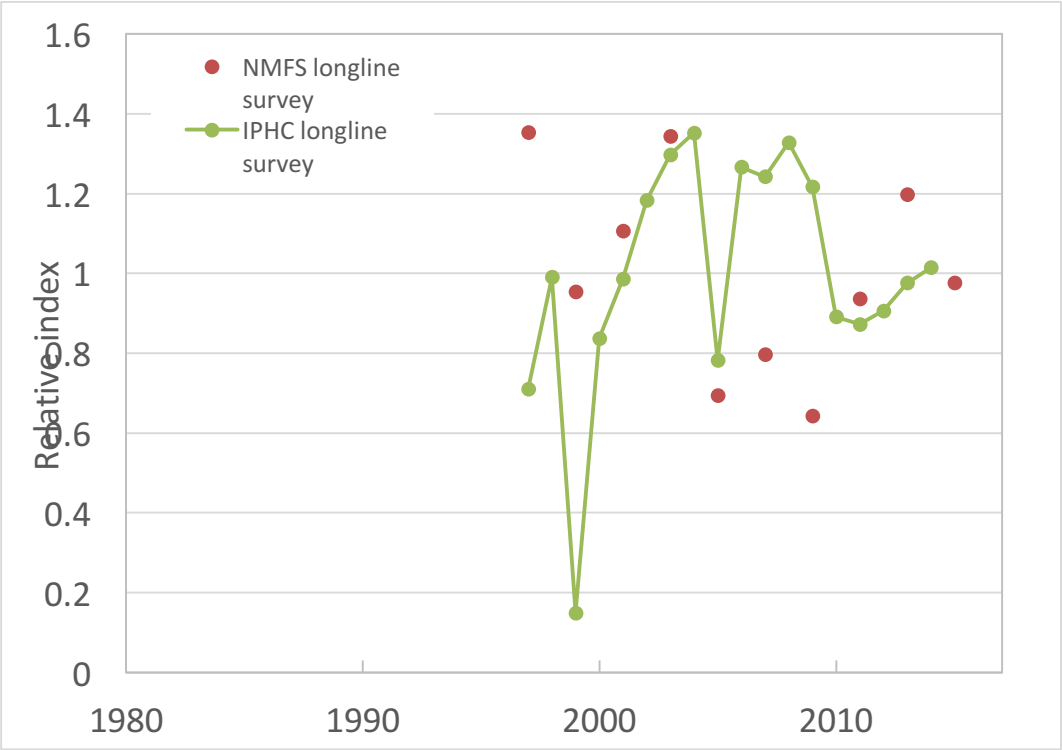

Figure 8: Relative indices of stock size from the AFSC longline survey and the IPHC longline survey (adapted from spreadsheet "*Survey index comparison (trawl surveys, longline surveys).xlsx*" prepared by the assessment team).

Similar to the IPHC longline survey, there are no objective reasons to reject the AFSC longline survey as an index of stock size. The AFSC longline survey should also be thoroughly investigated and used in the assessment unless fatal flaws in the data, in the data treatment or in the survey methodology are identified.

It is only by analyzing additional data that confidence will increase in the model results. Given the widely different results that can be obtained with SS3 (Figure 4), and the volatility of some of those results, it is not be possible to model oneself out of the uncertainty. Only careful examination and inclusion of informative additional data will allow that.

The discussion above is based on examination of data from the Eastern Bering Sea surveys, but the conclusions and recommendations also hold for the Aleutian Islands data and assessment.

2. Evaluate and provide recommendations on model structure, assumptions, and estimation procedures. In particular:

a. How should the various data sets be weighted?

Stock Synthesis is a very flexible stock assessment framework. Giving different weights to the various data sources, and depending on assumptions (e. g. fixed parameters), very different results in terms of absolute stock size, but also sometimes in terms of trends, can be obtained (Figure 4). This can also occur with other assessment frameworks, but because of SS3's flexibility, the problem is more severe.

Generally speaking, indices of abundance should be given more weight in the assessment than length composition. Age composition, particularly from surveys or other indices of abundance can be very informative if analyzed and used appropriately. Information in the length composition is at best indirect information on changes in stock size and it may be misleading if substantial changes in growth occur over time (Figure 11). In almost every stock where growth information is available by year, growth has been found to vary with trends over time, sometimes quite considerably. SS3 does allow for time varying growth, but without external information, it is unlikely to be able to estimate changes in growth correctly.

b. What form (i.e., Stock Synthesis "pattern") should be used for the selectivity functions?

Selectivity is a very important parameter in any assessment framework. Changes in growth, natural mortality, or fishing mortality can all be aliased as changes in selectivity. Several of the model configurations examined during the review had very peculiar selectivity patterns. This was identified in the pre-review material and in the presentations by the assessment team. Those were probably not real and were likely due to sampling problems or aliasing other changes. My preference would be to NOT allow too much flexibility in selectivity changes over time, and to NOT allow strange patterns (e.g. figures 2.1.3 in the Eastern Bering Sea and 2A.11 and 2A.12 in the Aleutian Islands in the December 2015 SAFE report). If allowing these strange patterns is a condition of getting a good fit or convergence, this would be a sign that something else might be wrong. If allowed to change over time and age, the changes should be relatively smooth and not result in peculiar patterns.

During the meeting, Robin Cook noted that the ratio of catch at length in the longline commercial fishery to the survey catch at length is reasonably constant above a certain length. A possible interpretation is that domed selectivity estimated for the AFSC shelf survey could be an artifact. Data in the file "*Long-term sizecomp comparison (trawl surveys, longline surveys, longline fishery).xlsx*", the ratio of the longline commercial catch at length to the various population estimates at length from the surveys are plotted in Figure 9[2]. The ratio of the longline commercial catch at length to the ASFC shelf survey for the Eastern Bering Sea is consistent with the observed size composition (Figure 10). The longline commercial fishery catches very few Pacific cod less that 40cm and the ratio increases progressively from nearly zero at 40 cm to around 5-6 at 70 cm and the ratio is indeed relatively constant from 70cm or so. The ratio seems to decrease above 100cm but this could easily be the result of low sample size. The ratio being relatively constant at 70cm and above suggests that selectivity does not

[2] Note that the maximum for the vertical axis has been arbitrarily set at 10

decrease at those sizes in the AFSC shelf trawl survey, or that selectivity in the longline commercial fishery decreases at a similar rate. This is unlikely but not impossible. The link between selectivity in the AFSC shelf trawl survey and selectivity in the longline commercial fishery should be further investigated to guide modeling.

The longline surveys appear to have very low selectivity, lower than that of the commercial longline fishery (Figure 9), for size less than the 55 cm for the IPHC longline survey and less than 40 cm for the AFSC longline survey. Differences in selectivity between the two longline surveys may be due to the differences in the sizes they catch (Figure 7). The ratio of the commercial longline catch at length to the survey catch at length is near 1 for both surveys in the 60-70 cm range, but the ratios diverge thereafter. The IPHC longline survey appears to have higher selectivity for the larger size than the commercial longline fishery does, while the AFSC longline survey would have lower selectivity than the commercial longline fishery. The AFSC slope trawl survey shows a pattern similar to the AFSC longline survey. The reason(s) for the apparent differences in selectivity between the IPHC longline survey and the AFSC longline survey for lengths above 70cm should be further investigated.

This is but a quick examination of what the data are telling us in terms of selectivity. Modeling results would be expected to be consistent with those observations.

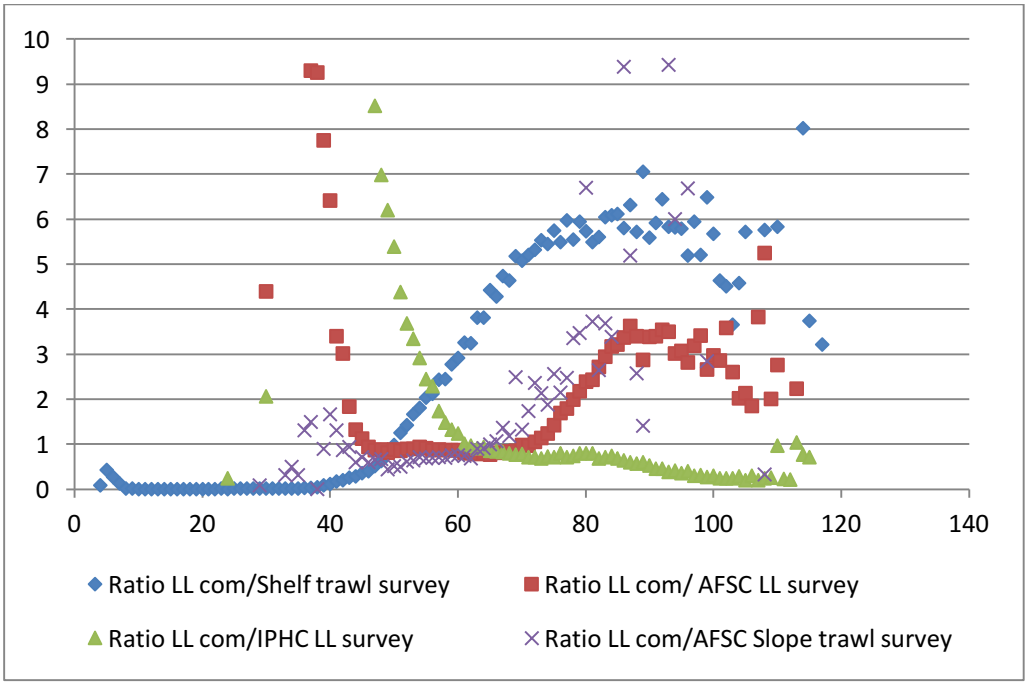

Figure 9: Ratio of the commercial longline catch at length to the population estimates at length from various surveys (data from "*Long-term sizecomp comparison (trawl surveys, longline surveys, longline fishery).xlsx*"). Note that the maximum for the vertical axis has been arbitrarily set at 10.

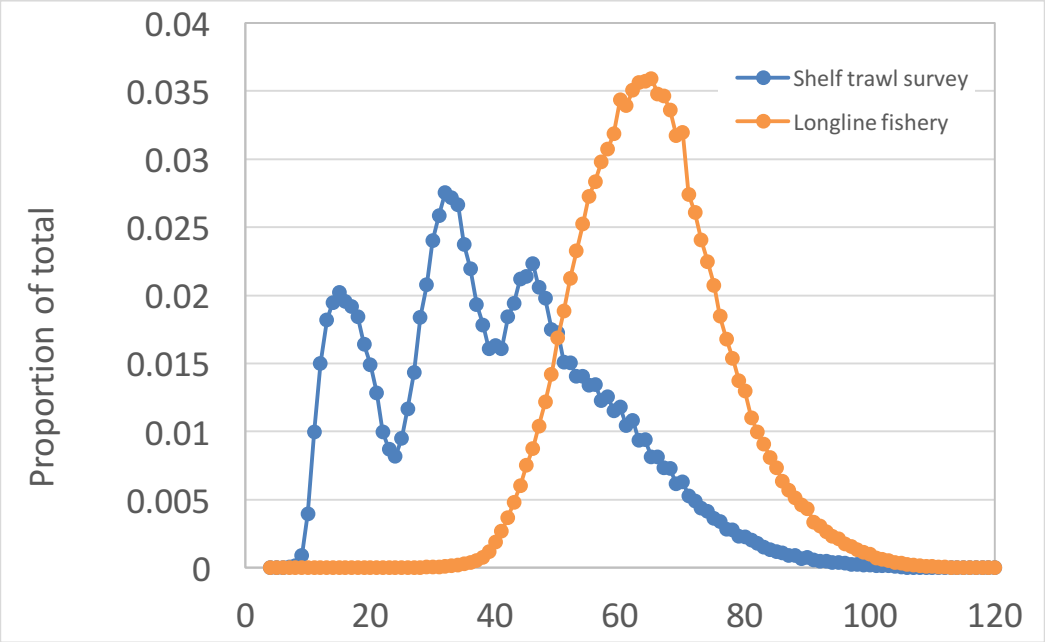

Figure 10: Size composition in the AFSC shelf trawl survey and in the longline commercial fishery (adapted from "*Long-term sizecomp comparison (trawl surveys, longline surveys, longline fishery).xlsx*").

c. Should the models be structured with respect to season?

In both areas, there seem to be a strong seasonal pattern in the fishery. Therefore, where the data are sufficient, it would be appropriate to structure the assessment model by season. However, for the Aleutian Islands assessment, the data may not be sufficient to structure by season.

d. Should the models be structured with respect to gear type?

Bottom trawl and longline are the two main gear types in the fisheries. Their size selectivities are expected to be different, and the models should definitely be structured with respect to gear type where the data are sufficient to do so.

e. How much time variability should be allowed, and in which parameters?

Selectivity, catchability of the surveys, natural mortality, and growth could be allowed to vary over time when there is independent information supporting that changes are happening. A change in the ratio between total catch biomass and biomass estimate in the survey that could not be explained by changes in management could be an indication that the catchability in the survey has changed. Changes in mesh sizes in the trawl or hook size in the longline fishery could be an indication of a stepped change in selectivity. Changes in the predator field or extreme weather events could be indications of changes in natural mortality. Because most of these parameters are interlinked, great care should be taken in allowing them to vary. Only those parameters where there is external information suggesting that changes are occurring should be allowed to vary, probably one at a time to avoid incorrect interpretation. Because of the flexibility in SS3 and because most of these parameters are interlinked allowing them to change may give strange results, such as highly anomalous selectivity.

f. What constraints, if any, should be placed on survey selectivity at older ages?

Peculiar selectivity patterns have been identified as a problem in the presentations by the assessment team. Based on the information in Figure 9, the selectivity for the AFSC shelf trawl survey in the Eastern Bering Sea at ages corresponding to 70 cm and larger would be expected to be reasonably flat. For both areas, sharp peak and valleys, unless based on external information, should be smoothed. As indicated above, strange, irregular patterns should be constrained to be smoother.

g. What constraints, if any, should be placed on survey catchability?

In the mid 1980s survey catchability was estimated for cod and haddock on the Eastern Scotian Shelf and in the Gulf of St. Lawrence in Eastern Canada[3]. Catchability for cod at the time was about 0.5 and for haddock it was close to 1. Vessels and gears have changed since and catchability estimates have also changed and in some areas they are now estimated to be greater than 1. Survey catchability is a scaling factor. In most assessment in the ICES area, survey catch per tow or catch per hour are used in the assessments and survey catchability is not an issue. It is, however, good practice to check every now and then if the assessment has the units more or less right by doing the areal expansion and comparing with the population estimates in the assessment.

Survey catchability smaller than 1 are relatively easy to rationalize e.g. by fish swimming faster than the net is towed, escaping above or below the net, or being more abundant in areas that are not surveyed. Survey catchability greater than 1 would happen if there is herding or if fish density in the surveyed area is expanded to areas where there are no fish, e.g. expanding flatfish density estimates from samples on smooth flatfish habitat to rough hard substrate that are not sampled and where flatfish are not present.

Catchability and natural mortality are interlinked. Considerable work was done in the Gulf of St. Lawrence in eastern Canada following the collapse of the groundfish stocks. Sinclair (2001[4]) estimated that natural mortality had likely increased for the southern Gulf of St. Lawrence stock. Subsequent stock assessments (e.g. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2007/RES2007_033_B.pdf and http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2007/RES2007_068_B.pdf) have used time varying natural mortality, but Canadian scientists warned that " *Estimation of M can be confounded by changes in survey catchability and fishery catch reporting, and may be sensitive to assumptions and constraints applied in the ADAPT estimation procedure."* (http://www.dfo-mpo.gc.ca/csas/Csas/status/2007/SAR-AS2007_002_E.pdf). Therefore, estimating catchability and natural mortality simultaneously would be challenging in the absence of external information.

External information indicative of changes in catchability could be changes in gears in the surveys or changes in predator abundance. Changes in catchability of pelagic species has been hypothesized to explain apparent increases of small pelagics in Eastern Canada after the

[3] Sinclair, M., J.-J. Maguire, P. Koeller and J.S. Scott. 1984. Trophic dynamic models in light of current resource inventory data and stock assessment results. ICES Rapp. P.-V. 183: 269-284

[4] Sinclair, A.F. 2001. Natural mortality of cod (Gadus morhua) in the Southern Gulf of St. Lawrence. IJMS 58: 1-10.

collapse of groundfishes[5] but this has been challenged[6]. Catchability in longline surveys could occur if high prey abundance in the water decreases the attractiveness of baited hooks[7].

This being said, Pacific cod appears to be a relatively well behaved species as far as trawl surveys are concerned. Survey catchability estimates between 0.5 and 1.5 would not seem to be cause for concern. The assessment team, the PDT and the SSC are concerned that catchability less than 1 imply very large biomass estimates. As indicated above, I do not share that concern (within limits of course). Catchability of the trawl survey in the Aleutian Islands area would be expected to be more uncertain than in the Eastern Bering Sea area because bottom topography is likely rougher and more diverse in the Aleutian Islands area than in the Eastern Bering Sea area.

h. How should large gradients be dealt with in otherwise apparently converged models?

Stock Synthesis User Manual version 3.24s, page 27, states: "*When using more population length bins than data bins, SS will run slower (more calculations to do), the calculated weights at age will be less aliased by the bin structure, and you may or may not get better fits to your data.*

While exploring the performance of models with finer bin structure, a potentially pathological situation has been identified. When the bin structure is coarse (note that some applications have used 10 cm bin widths for the largest fish), it is possible for a selectivity slope parameter or a retention parameter to become so steep that all of the action occurs within the range of a single size bin. In this case, the model will lose the gradient of the logL with respect to that parameter and convergence will be hampered. A generic guidance to avoid this situation is not yet available."

I have no further advice on how to deal with large gradient than what is said in the Stock Synthesis User Manual.

Changes in growth

For the Eastern Bering Sea, weights at age in the survey (from the preliminary assessment data file) show trends over time that seem to be year-class specific. It could be worth investigating further changes in growth (Figure 11), particularly with respect to the implications for the

[5] McQuinn, I. H. 2009. Pelagic fish outburst or suprabenthic habitat occupation: legacy of the Atlantic cod (Gadus morhua) collapse in eastern Canada. Canadian Journal of Fisheries and Aquatic Sciences, 66: 2256–2262.

[6] Frank, K. T., Leggett, W. C., Petrie, B., Fisher, J. A. D., Shackell, N. L., and Taggart, C. T. Pelagic fish outbreak in the Northwest Atlantic - reality or illusion? – ICES Journal of Marine Science, doi.10.1093/icesjms/fst111.

[7] Steingrund, P., Clementsen, D.H., Mouritsen, H. 2009. Higher food abundance reduces the catchability of cod (Gadus morhua) to longlines on the Faroe Plateau. Fisheries Research 100 (2009) 230–239.

assessment as growth changes may have an influence on fishing mortality and population estimates.

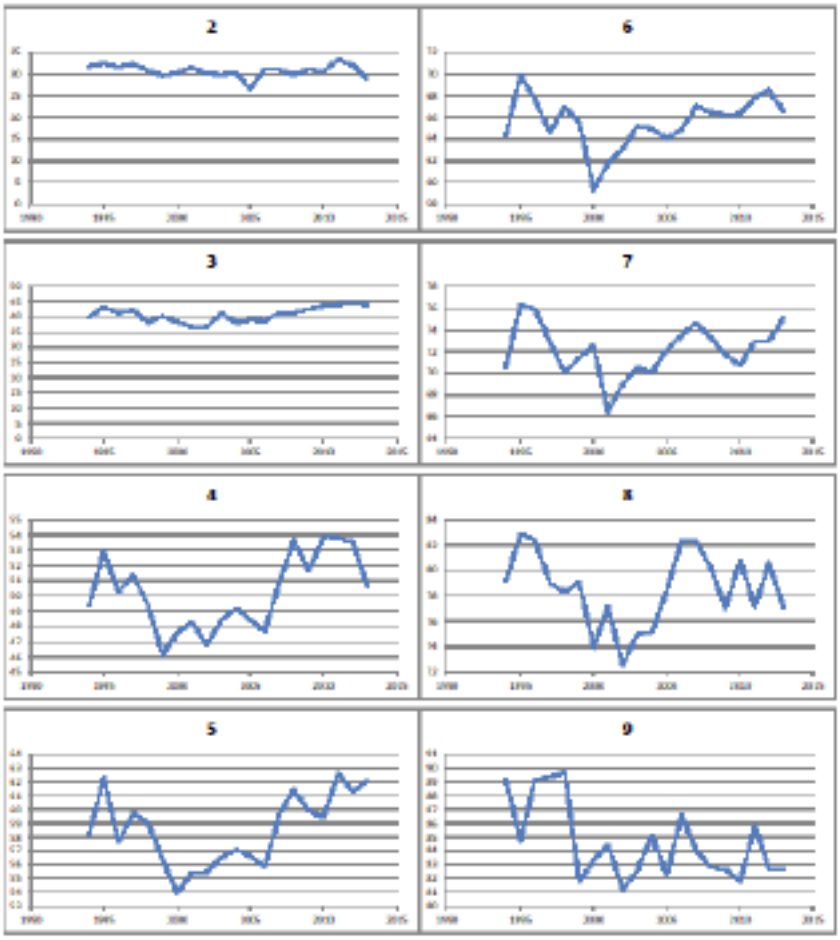

Figure 11: Eastern Bering Sea weights at age versus time. Data from the input file of the preliminary assessment.

Recruitment index

For the Eastern Bering Sea, the population estimates in the AFSC shelf trawl survey seem to be reasonably consistent for the first 3 age groups or so with reasonably good year-class tracking (Figure 12). If the AFSC shelf trawl survey for the Eastern Bering Sea is indeed following year-classes reasonably well, it could provide at least 3 successive estimates of year-class size and this could be used to obtain reasonably reliable estimates of year-class sizes.

In my cursory comparison of the AFSC shelf trawl survey length frequencies with the age frequencies in the same survey, I got the impression that the smallest modal length group was sometimes aged as age 1 and in other cases as age zero. This should be verified.

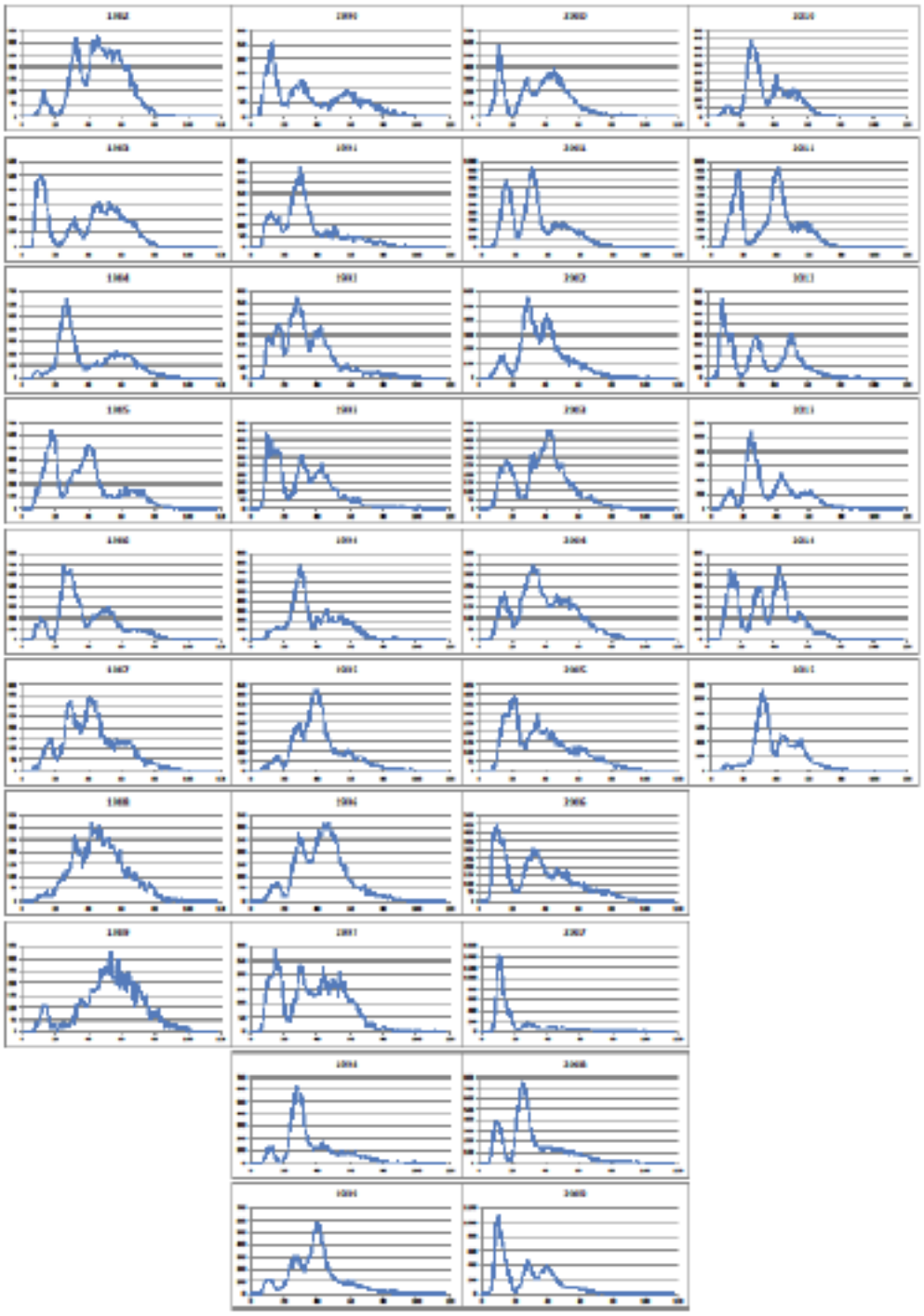

Figure 12: Eastern Bering Sea length frequencies in the AFSC trawl shelf survey.

Exploitation rate

The ratio of the commercial catch in tons to the survey biomass estimate in tons should be an indication of exploitation rate (relative if the catch and survey biomass are not in the same units). Figure 13, using data from run 15.6 for the Eastern Bering Sea shows the catch/survey

ratio in biomass compared with the fishing mortality estimate for the same model. The results suggest that fishing mortality in model 15.6 could be overestimated in recent years. Unless the catchability of the survey has changed, the results below suggest that F has been lower than average since about 2007. The correlation between the catch/survey ratio and F is low (0.009).

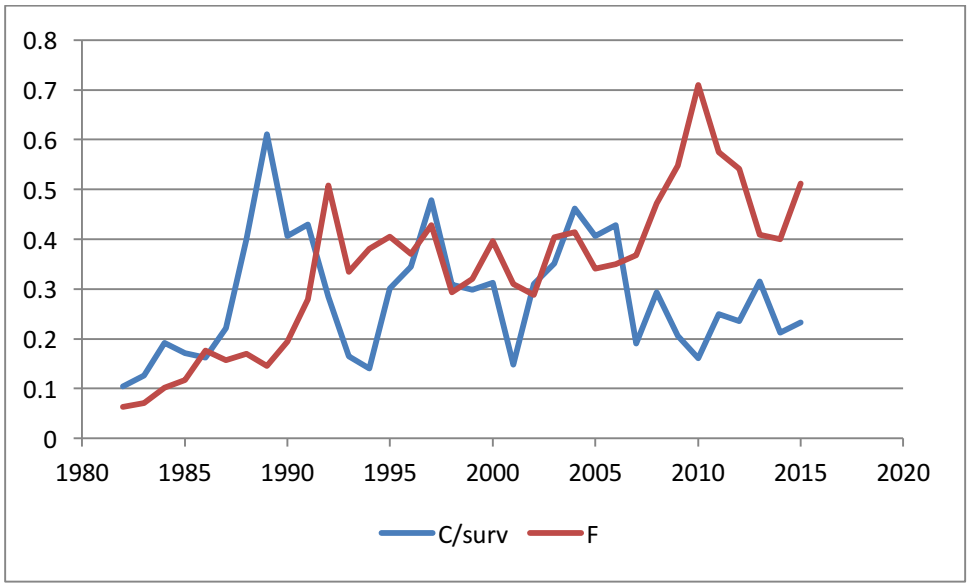

Figure 13: Ratio of catch biomass to survey biomass compared with F from model 15.6 for the Eastern Bering Sea.

Reliability of total catch estimates

For the Aleutian Islands assessment model 15.7, there is reasonably good agreement between fishing mortality estimates in the assessment and catch (Figure 14) except in the late 1980s and in 2010 when fishing mortality estimates suggests that mortality has been higher. It might be worth investigating if additional sources of mortality (e.g. increased M) occurred in those years.

The correlation between F from the assessment (model 15.7) and the ratio of catch to survey biomass is higher (Figure 15) for the Aleutian Islands (0.47).

Stock structure

In the Aleutian Islands area, it is unlikely that there is a single stock in the traditional understanding of the concept. Instead, a number of local spawning would be expected with limited mixing during spawning. While these different spawning units may react similarly to changes in the environment and show similar trends in recruitment, they are unlikely to form a single homogeneous biological unit. It is likely impractical to do individual stock assessments for each of the individual units, and lumping all units into a single assessment with indices of abundance for only a few of them may increase the risk to less productive units. Simpler form of monitoring and management, in close cooperation with the industry and possibly NGOs, could be a better way of protecting the resources and managing the fisheries.

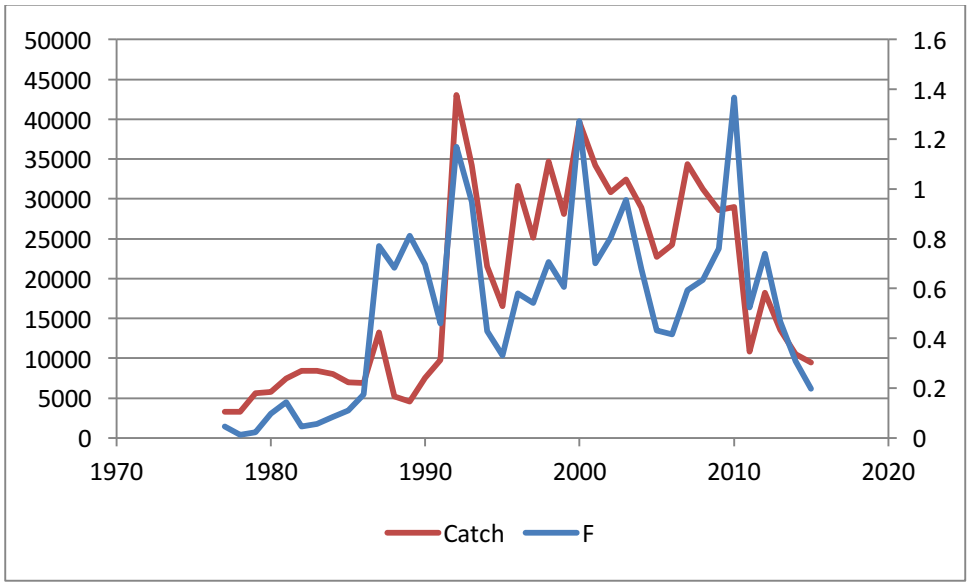

Figure 14: Aleutian Island catch and fishing mortality estimates from model 15.7 versus time.

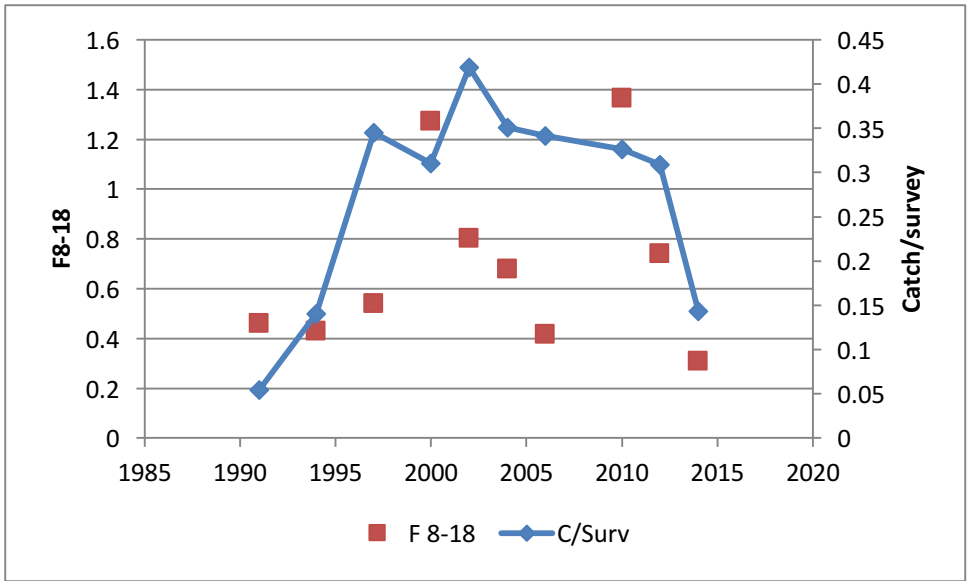

Figure 15: Aleutian Island fishing mortality from model 15.7 and catch in tons/ survey biomass in tons versus time.

Conclusions and Recommendations in accordance with the ToRs.

For the IPHC longline survey, the appropriateness of the data and how it was treated to calculate an index should be further verified between now and the assessment meeting later in the year. What data were used and how they were used should also be documented. The apparent anomalies in 1999 and 2005 warrant further investigations to try to identify what might cause them. If there are valid reasons to exclude those two points, it might be possible to reconcile the IPHC longline and AFSC shelf trawl survey time series taking into account that they sample different size groups. From what was discussed during the meeting and the documentation reviewed, there are no objective reasons to reject the IPHC longline survey as an index of stock size, assuming it has been correctly put together and calculated. The IPHC longline survey data should be thoroughly investigated. It should be used in the assessment unless fatal flaws in the data, in the treatment of the data or in the survey methodology are identified.

Similar to the IPHC longline survey, there are no objective reasons to reject the AFSC longline survey as an index of stock size. The AFSC longline survey should also be thoroughly investigated and used in the assessment unless fatal flaws in the data, in the data treatment or in the survey methodology are identified.

The discussion above is based on examination of data from the Eastern Bering Sea surveys, but the conclusions and recommendations also hold for the Aleutian Islands data and assessment.

With respect to weighting different data sets, indices of abundance should be given more weight in the assessment than length composition. Age composition, particularly from surveys or other indices of abundance can be very informative if analyzed and used appropriately. Information in the length composition is at best indirect information on changes in stock size and it may be misleading if substantial changes in growth occur over time (Figure 11).

Regarding the form of the selectivity function, my preference would be to NOT allow too much flexibility in selectivity changes over time and to NOT allow strange patterns (e.g. figures 2.1.3 in the Eastern Bering Sea, and 2A.11 and 2A.12 in the Aleutian Islands in the December 2015 SAFE report). If allowing these strange patterns is a condition of getting a good fit or convergence, this would be a sign that something else might be wrong. If allowed to change over time and age, the changes should be relatively smooth and not result in peculiar patterns. The ratio of catch at length in the longline commercial fishery to the survey catch at length being relatively constant at 70cm and above suggests that selectivity does not decrease at those sizes in the AFSC shelf trawl survey, or that selectivity in the longline commercial fishery decreases at a similar rate. This is unlikely but not impossible. The link between selectivity in the AFSC shelf trawl survey and selectivity in the longline commercial fishery should be further

investigated to guide modeling. The reason(s) for the apparent differences in selectivity between the IPHC longline survey and the AFSC longline survey for lengths above 70cm should be further investigated.

Where the data are sufficient, it would be appropriate to structure the assessment model by season.

Bottom trawl and longline are the two main gear types in the fisheries. Their size selectivity are expected to be different and the models should definitely be structured with respect to gear type where the data are sufficient to do so.

Selectivity, catchability of the surveys, natural mortality, and growth could be allowed to vary over time when there is independent information supporting that changes is happening. Because most of these parameters are interlinked, great care should be taken in allowing them to vary. Only those parameters where there is external information suggesting that changes is occurring should be allowed to vary, probably one at a time to avoid incorrect interpretation.

Based on the information in Figure 9, the selectivity for the AFSC shelf trawl survey in the Eastern Bering Sea at ages corresponding to 70 cm and larger would be expected be reasonably flat. For both areas, sharp peaks and valleys, unless based on external information, should be smoothed. As indicated above, strange, irregular patterns should be constrained to be smoother.

I have no further advice on how to deal with large gradient than what is said in the Stock Synthesis User Manual.

It could be worth investigating further changes in growth (Figure 11), particularly with respect to the implications for the assessment as growth changes may have an influence on fishing mortality and population estimates.

If the AFSC shelf trawl survey for the Eastern Bering Sea is indeed following year-classes reasonably well, it could provide at least 3 successive estimates of year-class size and this could be used to obtain reasonably reliable estimates of year-class sizes.

In my cursory comparison of the AFSC shelf trawl survey length frequencies with the age frequencies in the same survey, I got the impression that the smallest modal length group was sometimes aged as age 1 and in other cases as age zero. This should be verified.

Figure 13, using data from run 15.6 for the Eastern Bering Sea shows the catch/survey ratio in biomass compared with the fishing mortality estimate for the same model. The results suggest that fishing mortality in model 15.6 could be overestimated in recent years.

For the Aleutian Islands assessment model 15.7, there is reasonably good agreement between fishing mortality estimates in the assessment and catch (Figure 14) except in the late 1980s and in 2010 when fishing mortality estimates suggests that mortality has been higher. It might be worth investigating if additional sources of mortality (e.g. increased M) occurred in those years.

In the Aleutian Islands area, it is unlikely that there is a single stock in the traditional understanding of the concept. Simpler form of monitoring and management, in close cooperation with the industry and possibly NGOs, could be a better way of protecting the resources and managing the fisheries.

One cannot model oneself out of lack of data, particularly for the Aleutian Islands assessment. Stock Synthesis has so much flexibility that, given sufficient time, a skilled user can probably get almost any stock trend from a dataset. Indices of abundance should be given more weight in the assessment than length composition. Age composition, particularly from the commercial fishery, but also from surveys or other indices of abundance can be very informative if analyzed appropriately. Information in the length composition is at best indirect information on changes in stock size. In almost every stock where growth information is available by year, growth has been found to vary with trends over time, sometimes quite considerably and this could very well be the case here for the Eastern Bering Sea (Figure 11). SS3 does allow for time varying growth, but without external information, it is unlikely to be able to estimate changes in growth correctly.

Analytical retrospective analyses are routinely done for both stocks. Historical retrospective, where the successive accepted assessment are also informative and should be done to indicate how consistent the assessments have been over time.

Simpler models, e.g. like Robin Cook's or surplus production models should be investigated. It is not necessary to go to Ensemble modeling, but looking at more than one modeling framework might be informative.

The review panel chair did excellent work at keeping the discussions flowing smoothly to ensure that work progressed at a good pace and sensibly. The assessment team was very useful, cooperative and their help is greatly appreciated. This was a pre-assessment review where the CIE panelists did not have to agree or disagree with one or more assessments. Instead, the purpose was to get input into possible avenues to explore or others to avoid. The assessment team has done a very thorough job at preparing runs before the meeting and at replying to requests during the meeting.

Appendix 1: Bibliography of materials provided for review

The material provided for review before the meeting can be found at http://www.afsc.noaa.gov/REFM/Stocks/plan_team/2016pcodCIE/draft_assessments.htm

- Assessment of the Pacific cod stock in the eastern Bering Sea (220 p.), including a history of alternative models developed for assessing Pacific cod in the EBS (Appendix 2.3)
- Assessment of the Pacific cod stock in the Aleutian Islands (143 p.), including a history of alternative models developed for assessing Pacific cod in the AI (Appendix 2A.3)
- Excerpt from the BSAI Groundfish Plan Team minutes of November 2015
- Excerpt from the SSC minutes of December 2015
- FLC comments - Pcod CIE review 2016
- Thompson random effects variance estimation (version of 6-26-15, with figure legends)
- Weinberg et al. manuscript on field studies of selectivity (provisionally accepted)

Appendix 2: Statement of Work

External Independent Peer Review by the Center for Independent Experts

Assessment of the Pacific cod stocks in the Eastern Bering Sea and Aleutian Islands

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: Despite exploration of a large number of alternative models and multiple levels of review each year, the annual assessments of the Pacific cod stocks in the EBS and AI continue to be controversial. Of particular concern currently is the estimation of catchability and selectivity for the bottom trawl survey in each area. However, review is requested of all aspects of the stock assessment models. The combined Pacific cod fisheries in the EBS and AI are of great economic importance, ranking second only to pollock in recent years. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of stock assessment methods in general, and preferably Stock Synthesis in particular. Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting ***scheduled in Seattle, WA during February 16-19, 2016.***

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/
http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Assessment of the Pacific cod stock in the eastern Bering Sea (220 p.), including a history of alternative models developed for assessing Pacific cod in the EBS (Appendix 2.3)

Assessment of the Pacific cod stock in the Aleutian Islands (143 p.), including a history of alternative models developed for assessing Pacific cod in the AI (Appendix 2A.3)

Comments on the final 2015 EBS and AI Pacific cod assessments by the Plan Team and SSC

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs cannot be made during the peer review, and any**

SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator. Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

The review meeting will include three main parts: The first will consist of a series of presentations with follow-up questions and discussions by CIE reviewers, and will be chaired by an AFSC scientist or supervisor. The second will consist of real-time model runs and evaluations conducted in an informal workshop setting, and will be chaired jointly by the CIE reviewers. The third, time permitting, will consist of initial report writing by the CIE reviewers, with opportunity for additional questions of the assessment author.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting ***scheduled at the Alaska Fisheries Science Center in Seattle, WA during February 16-19, 2016.***
3) Participate at the peer review meeting ***tentatively scheduled at the Alaska Fisheries Science Center in Seattle, WA during February 16-19, 2016*** as specified herein, and conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than ***March 4, 2016***, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to mshivlani@ntvifederal.net, and CIE Regional

Coordinator, via email to Dr. David Die ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following ***tentative*** schedule.

January 11, 2016	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
February 1, 2016	NMFS Project Contact sends the CIE Reviewers the pre-review documents
February 16-19, 2016	Each reviewer participates and conducts an independent peer review during the panel review meeting
March 4, 2016	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
March 18, 2016	CIE submits CIE independent peer review reports to the COTR
March 25, 2016	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on

compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) The CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) The CIE report shall address each ToR as specified in **Annex 2**,
(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

Allen Shimada
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
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Manoj Shivlani, CIE Lead Coordinator
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Key Personnel:

NMFS Project Contact:

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c/o Department of Fisheries and Wildlife
Oregon State University
104 Nash Hall, Corvallis, OR 97331
Phone: 541-737-9318
grant.thompson@noaa.gov

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Assessment of the Pacific cod stocks in the Eastern Bering Sea and Aleutian Islands

3. Evaluate and provide recommendations on data used in the assessment models. In particular:
    a. Should data from the IPHC longline survey be used in either assessment?
    b. Should data from the NMFS longline survey be used in either assessment?
4. Evaluate and provide recommendations on model structure, assumptions, and estimation procedures. In particular:
    a. How should the various data sets be weighted?
    b. What form (i.e., Stock Synthesis "pattern") should be used for the selectivity functions?
    c. Should the models be structured with respect to season?
    d. Should the models be structured with respect to gear type?
    e. How much time variability should be allowed, and in which parameters?
    f. What constraints, if any, should be placed on survey selectivity at older ages?
    g. What constraints, if any, should be placed on survey catchability?
    h. How should large gradients be dealt with in otherwise apparently converged models?
    i. Anything else on which the reviewers care to comment.

Annex 3: Tentative Agenda
CIE Review of the EBS and AI Pacific cod stock assessment models

Alaska Fisheries Science Center
7600 Sand Point Way NE, Seattle, WA 98115
February 16-19, 2016
Building 4; Room 2039 (except Wednesday afternoon), Room 2143 (Wednesday afternoon)

Review panel chair: Anne Hollowed, Anne.Hollowed@noaa.gov
Senior assessment author: Grant Thompson, Grant.Thompson@noaa.gov
Security and check-in: Sandra Lowe, Sandra.Lowe@noaa.gov (206)526-4230
Sessions will run from 9 a.m. to 5 p.m. each day, with time for lunch and morning and afternoon breaks. Discussion will be open to everyone, with priority given to the panel and senior assessment author.

Tuesday, February 16
Preliminaries:
09:00 Introductions and adoption of agenda—Anne
Data sources (current and potential):
09:10 Overview of data types used in the assessments—Grant
09:20 Catch accounting system and in-season management—AKRO SF Division (via WebEx)
09:50 Observer program—AFSC FMA Division
10:20 Break
10:30 EBS trawl survey—AFSC RACE Division
11:00 AI trawl survey—AFSC RACE Division
11:30 IPHC longline survey—IPHC
12:00 Lunch
13:00 NMFS longline survey—AFSC Auke Bay Laboratory (via WebEx)
13:30 Age composition and mean-length-at-age data—AFSC REFM Division
Assessment models:
- 14:00 Assessment history—Grant
- 15:00 Break
- 15:10 Current assessments—Grant
- 16:10 Discussion—Everyone
- 16:40 Assignments for models to be presented on Wednesday—Panel

Wednesday, February 17 and Thursday, February 18
Review of models assigned the previous day—Grant
Discussion, real-time model runs—Everyone
Assignments for models to be presented the following day—Panel

Friday, February 19
Review of models assigned on Thursday—Grant
Discussion, real-time model runs—Everyone
Report writing (time permitting)—Panel

Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

The CIE panelists were Robin Cook, Neil Klaer and Jean-Jacques Maguire. Jean-Jacques Maguire missed the first day of the meeting because its connecting flight in JFK was cancelled due to the closure of the airport because of freezing rain.

The review panel chair did excellent work at keeping the discussions flowing smoothly to ensure that work progressed at a good pace and sensibly. The assessment team was very useful, cooperative and their help is greatly appreciated. This was a pre-assessment review where the CIE panelists did not have to agree or disagree with one or more assessments. Instead, the purpose was to get input into possible avenues to explore or others to avoid. The assessment team has done a very thorough job at preparing runs before the meeting and at replying to requests during the meeting.

Participants List
CIE Review of the EBS and AI Pacific cod stock assessment models
Alaska Fisheries Science Center (AFSC)
7600 Sand Point Way NE, Seattle, WA 98115
February 16-19, 2016

Review panel chair: Anne Hollowed, Anne.Hollowed@noaa.gov
Senior assessment author: Grant Thompson, Grant.Thompson@noaa.gov
Support assessment author: Steve Barbeaux, Steve.Barbeaux@noaa.gov

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Chad See	Freezer Longline Coalition	Chadsee@freezerlongline.bz
Gerry Merrigan	Freezer Longline Coalition	Merrigan@oci.net
Mike Peterson	Interested Fisherman	
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